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To: Dr. D. Mills
Director of Research

HOLOGRAPHY FINDS DEFECTIVE MORTAR JOINT IN CONCRETE BLOCK WALL

David L. Mader and Ed J. McColm

A defective mortar joint in a concrete block wall has been detected by holography. This finding has been supported by ultrasonic measurements and has been confirmed by direct observation of core samples taken from the wall.

INTRODUCTION

Detection of a defective mortar joint with holography was an unexpected outcome of a test on the usefulness of a pulsed laser for holography in the field environment. In the test conducted in our holography laboratory, it was decided to simulate the field environment by making a hologram of the wall of the laboratory. In this way the object being holographed was no longer on the vibration isolation table which is the environment needed for holography with a continuous laser. As it turned out, the area of the wall observed had a mortar joint where straight-line holographic fringes made a right angle bend as seen below.

Defective mortar joint ->

The area on the wall seen in the photo above is about half a metre square and it covers about three courses of concrete blocks. There were two laser pulses utilized to create the above fringe pattern: one to make the hologram, and a second pulse to both illuminate the wall a second time and to play back the hologram. For the second pulse, the wall was stressed by pushing on it.

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HOLOGRAPHIC NONDESTRUCTIVE TESTING

Holographic nondestructive testing (HNDT) is a term coined by early workers in holography who quickly discovered that holography provided a way to do interferometry on ordinary objects. Previously, only mirrors, lenses and optical components could be tested by interferometry, but now holographic interferometry provides a sensitive, noncontact method to visualize strain on a matte object caused by a test load. As envisioned by the holographic pioneers, HNDT works by highlighting weak areas in a mechanical component as areas where the fringe pattern is different. Hidden flaws are revealed by a concentration of fringes in the interferogram, and cracks that reach the surface cause discontinuities in the fringes. An early success story in HNDT was tire testing in which bonding failures in the walls of tires were easy to see with holography, while X-rays would not detect such defects, and ultrasonics would give confusing signals from the reinforcing plies. A research effort has been underway at Ontario Hydro since 1983 to identify electric utility uses for HNDT as can be seen from References 1 to 14. An overview of the capabilities of holography seen in the laboratory and efforts toward field application are given in References 1 and 5.

The apparatus described there/1,5/ and shown here in Fig 1 for field holography was reassembled for this work with a new pulsed laser borrowed from the Ontario Laser and Lightwave Research Centre housed at the University of Toronto. This Quantel Model YG661-20 YAG laser was able to produce high energy pulses of 300 mJ at a pulse repetition rate of 20 Hz and was used with a frequency doubling crystal to produce green light. It was equipped with an injection seeding laser which enabled the pulsed output to have a coherence length essentially equal to the spatial length of the pulse. Since the pulse duration was 5 ns, the light pulse was 1.5 m long in the direction of travel leading to a maximum depth of field that could be holographed on an object of 1.5 m.

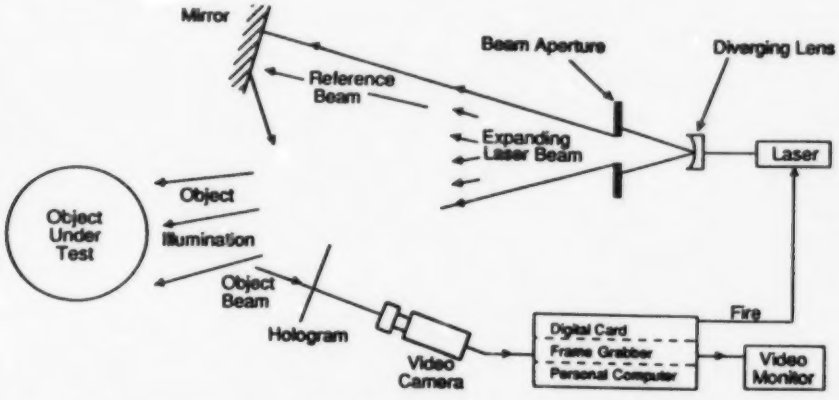

Fig 1. Apparatus for pulsed holography and real time interferometry.

Holograms were successfully made of objects mounted on the same optical table where the laser and other components were assembled. Then to simulate field work, a hologram was made of the wall of the holography laboratory beyond the end of the optical table. Now the object to be holographed no longer enjoyed vibration isolation, and use of a continuous laser would not be successful. The point of using a pulsed laser is that the hologram can be fully exposed before any components in the system, including the object, can move more than a quarter of a wavelength, a condition for a successful hologram.

The holograms were made with a Newport "Instant Holocamera" which uses thermoplastic holographic plates rather than chemical films. These plates can be erased and reused a few hundred times. They are sensitized and developed *in situ* in the holocamera, and are ready to view about 10 seconds after exposure.

Interferometry was done with the real-time technique, in which the fringe pattern may be viewed live as the object is stressed. With the pulsed system shown in Fig 1, the interferogram was updated with each successive laser pulse. In this technique, two views of the object described below are superposed.

1. The image encoded in the hologram is viewed by shining the reference beam through it. This recreates the light reflected from the object when it was in its original (unstressed) condition.

2. The object is viewed directly through the hologram while the object is illuminated.

Optical interference occurs between these two beams of light from the object and it is seen to be covered by a fringe pattern. The fringe pattern (interferogram) is captured by a video camera and frame grabber and can be viewed on a video monitor. The fringe pattern is due to any movement of the object which may have occurred since the hologram was made.

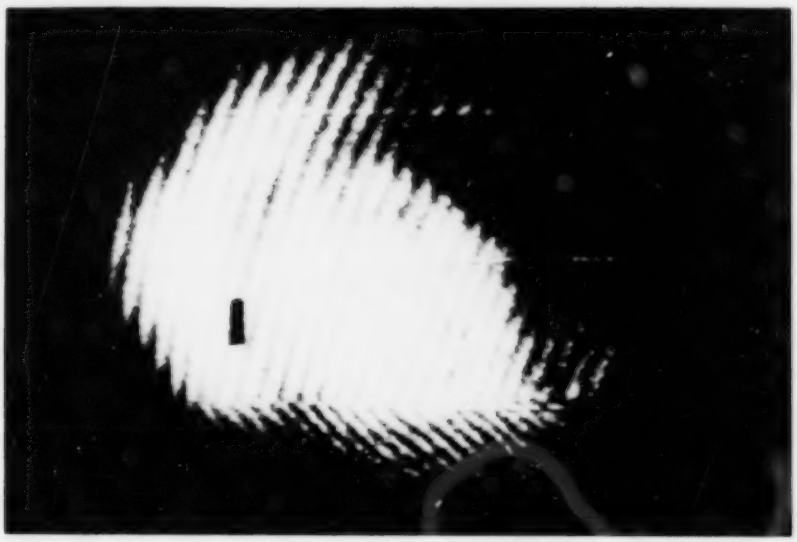

Fig 2. Fringe pattern obtained on wall by holographic interferometry.

In the experiment on the wall in the holography laboratory, the wall was stressed by pushing on it after the hologram was made. One characteristic of the fringe pattern seen in Fig 2 is that the fringes are approximately straight and evenly spaced which indicates the occurrence of

tilting of the wall as a whole. The other striking feature is the disruption in the fringes and their direction at one of the mortar joints. This means that the wall behaved as two separate plates which tilted differently when the wall was pushed. There were no visible cracks in the mortar joints.

Thus, holography detected a hidden anomaly in a concrete block structure.

ULTRASONIC INVESTIGATION

The mortar joint identified by the holography experiment was further investigated using a commercially available ultrasonic pulse velocity measurement instrument (PUNDIT.) This instrument operates by measuring the time required for an ultrasonic pulse wave to travel between two transducers (transmitter and receiver). The apparent distance between the transducers is measured along the shortest path through solid material and an apparent velocity for the pulse waves is calculated using this distance and the measured transit time. Since a wave travels around cracks and voids, the actual path the wave takes may be greater than the apparent distance between the transducers. Thus, the apparent velocity is less when defects are present.

First, the blocks themselves were investigated to determine whether there were any differences in the blocks above and below the suspect mortar joint. Readings of the pulse transit time were taken through the wall at three locations on six separate blocks. The results shown in Table A1, Appendix A, indicate that the blocks are similar above and below the suspect joint.

To investigate the horizontal joints, readings were taken through the wall across the joints at four separate locations. A total of five joints were investigated, including two above and two below the suspect joint. From the results given in Table A2, Appendix A, it can be seen that although the average velocity varied (4000 to 4700 m/s), the joint identified by holography exhibited a significantly lower velocity (2800 m/s). The low velocity may be due to a crack, voids, or some other discontinuity along the path of the pulse wave.

The ultrasonic investigation appears to support the finding of the holography experiment and to show that the integrity of the joint identified by holography is less than that of the joints above and below it.

CORE SAMPLES OF MORTAR JOINTS

Concrete cores were drilled from the joints to confirm the results obtained from the holographic and the ultrasonic investigations. A small portable drill was used to obtain three cores of 73 mm diameter from the suspect joint and the ones above and below it.

Core 1, taken from the suspect joint, was retrieved in two sections with the failure plane between the mortar and the upper block. The other two cores (Cores 2 and 3), drilled from the joints above and below Core 1, were retrieved intact and appeared to contain more mortar than Core 1. The joints were viewed microscopically and, except for the one that failed during drilling, they all appear sound.

The coring has confirmed that a defective mortar joint exists in the wall.

CONCLUSIONS

A defective mortar joint in a concrete block wall has been detected by holography. This finding has been supported by ultrasonic measurements and has been confirmed by direct observation of core samples taken from the wall.

The holographic experiment was done with a pulsed laser borrowed to demonstrate the feasibility of performing holography under field conditions. It is recommended that a portable pulsed holography system be set up to assess its usefulness in field applications at Ontario Hydro.

In concrete technology, potential application areas would be:

1. Laboratory tests on concrete samples to evaluate stress-strain distribution during various loading conditions.

2. Observation of stress concentrations at critical locations on large concrete structures when load is applied.

Approved:

A.F. Baljet
Manager
Electrical Research Dept

Submitted by:

D.L. Mader
Associate Research Scientist
Science Section

Approved:

T.W. Klym
Manager
Civil Research Dept

Submitted by:

E.J. McColm
Engineer
Concrete Technology Section

DLM/EJM:CB/mao

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APPENDIX A - ULTRASONIC PULSE VELOCITY READINGS

HOLOGRAPHY LABORATORY WEST WALL

Table A1
Pulse Velocity Through Blocks (m/s)

Block Identification	Location Along Blocks (see Fig A2)					
	1/4 L		1/2 L		3/4 L	
(See Fig A1)	Travel Time (μ/s)	Velocity* (m/s)	Travel Time (μ/s)	Velocity** (m/s)	Travel Time (μ/s)	Velocity* (m/s)
A	76	5200	37	5100	66	6000
B	68	5800	37	5100	66	6000
C	72	5500	37	5100	61	6500
Average	72	5500	37	5100	64	6200
D	67	5900	39	4900	77	5100
E	71	5500	39	4900	66	6000
F	75	5200	39	4900	72	5500
Average	71	5500	39	4900	72	5500

* Velocities were calculated assuming the pulse traveled over a path length of 395 mm as shown in Fig A3.

** Velocities were calculated assuming the pulse traveled directly through the blocks over a path length of 190 mm, equal to the thickness of the wall.

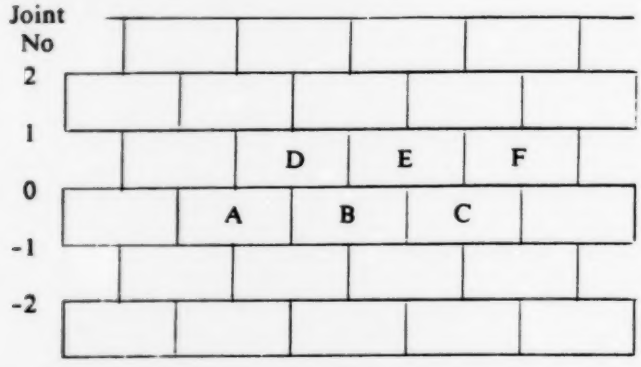

Fig A1. Holography laboratory west wall showing the location of the blocks (A to F) and joints (2 to -2) investigated.

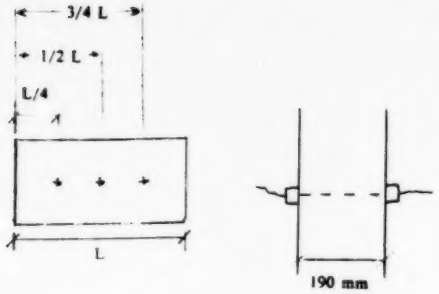

Fig A2. Transducer locations on the blocks investigated.

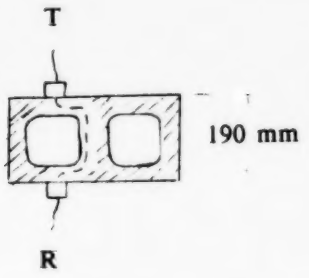

Fig A3. Plan view of blocks showing path of sound waves at 1/4 L and 3/4 L. Path TR = 395 mm.

Table A2
Pulse Velocity Through Joints (m/s)*

	Joint 2**	Joint 1**	Joint 0**	Joint -1**	Joint -2**
	4700	4400	3400	4800	3400
	4600	3900	2800	4800	4000
	4500	3800	2600	4800	4500
	4300	3900	2400	4500	4700
Average	4400	4000	2800	4700	4400

* Readings were taken diagonally through the wall at each joint (see Fig A4). Path Length = 480 mm.

** For joint locations see Fig A1.

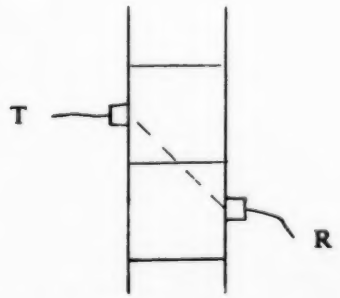

Fig A4. Cross section of wall showing location of transducers for investigation of joints. Path TR = 480 mm.